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SPECIFICATION

COLD STOCKER

Technical field

The present invention relates to a cold stocker that uses to a Stirling engine to cool the inside of a compartment thereof. A "cold stocker" is a concept encompassing appliances in general in which the temperature in a closed space thereof (referred to as the "compartment" thereof) is lowered for the purpose of preserving food and the like, and the specific product name thereof is not limited to "refrigerator", "freezer", "refrigerator-freezer", or the like.

Background art

In the refrigerating cycle of a cold stocker, a chlorofluorocarbon (CFC) or a hydrochlorofluorocarbon (HCFC) is used as a refrigerant. Since these refrigerants, when released into the atmosphere, more or less lead to the destruction of the ozone layer, the production and use thereof are globally regulated.

Hence, Stirling refrigerating engines, which do not use an ozone depleting substance as a refrigerant, have been attracting much attention. In a Stirling refrigerating engine, an inert gas such as Helium is used as a working fluid, and a piston and a displacer are moved by an externally supplied force to repeatedly compress and expand the working fluid, and thus a lower-temperature section (cold section) and a higher-temperature section (warm section) are formed. The cold section absorbs heat of the compartment of a cold stocker, and the warm section dissipates heat to the ambient environment. JP-A-H3-36468 discloses an example of a cold stocker incorporating a Stirling refrigerating engine.

Disclosure of the invention

A Stirling refrigerating engine has a compact structure and both its cold and warm section have small surface areas for its refrigerating capacity. Hence, the performance of a cold stocker greatly depends on how efficiently heat is absorbed and dissipated. JP-A-H3-36468 discloses a cold stocker in which a warm-side heat exchanger of a Stirling refrigerating engine is arranged in a heat dissipating path where an air flow is generated by a heat dissipating fan. Thus, heat is dissipated through the warm-side heat exchanger by forced air cooling.

In the forced air cooling method designed as just described, for the purpose of absorbing a sufficient amount of heat of the warm section having a small heat-transferring area, a radiator with a large number of densely arranged fins needs to be mounted to the warm section. Furthermore, a large amount of cooling air needs to be blown to the radiator. Such a structure is accompanied by inconveniences such as: dust clogging between the fins for dissipating heat; big noise caused by the blowing air; and a large amount of power consumed by the fan.

In addition, the air cooling method itself inherently suffers from a large thermal resistance and does not help achieve absorption of enough heat. This inconveniently prevents the difference between the temperature of the warm section and the ambient temperature from reducing quickly, which prevents the COP (coefficient of performance) of the Stirling refrigerating engine from being improved.

Moreover, in a cold stocker, gaskets fitted on the door thereof and part of the wall of the cold stocker surrounded by the gaskets make contact with cool air in the compartment thereof. As a result, heat is absorbed through the outer surface of the gaskets and part of the wall facing outside around the gaskets, and thus the moisture in the air condenses into dew.

The dew drips down to make the floor wet, and also causes the wall of the cold stocker made of a coated steel plate to develop rust. To prevent these inconveniences, in conventional cold stockers, electric heaters are arranged inside the walls near the gaskets for the purpose of preventing dew condensation, and this disadvantageously increases power consumption.

It is inevitable that frost deposits on a compartment-cooling heat exchanger of a cold stocker. If frost is left unremoved, the cooling capacity of the cold stocker is impaired, and hence periodic defrosting is required to restore the cooling capacity. Drain resulting from defrosting or from other causes is collected in a drain pan. To save the trouble of detaching the drain pan to discharge drain, a method is generally employed in which the drain pan is heated to promote evaporation of drainage. In a conventional cold stocker in which a compressor is used to compress the refrigerant, the heat resulting from compression of the refrigerant can be used to heat the drain pan. The cold stocker in which a Stirling refrigerating engine is incorporated, however, is not provided with a component equivalent to the conventional compressor, and thus an electric heater needs to be used to heat the drain pan, and this also causes the power consumption to increase.

An electric heater has conventionally been used to heat a compartment-cooling heat exchanger to remove the frost deposited thereon, and this also increases the power consumption.

The present invention has been made to overcome the above described inconveniences, and it is an object of the present invention to increase, in a cold stocker in which a Stirling refrigerating engine is incorporated to cool a compartment, the heat dissipation efficiency of the Stirling refrigerating engine so as to make the most of the refrigerating capacity of the Stirling refrigerating engine. It is also an object of the present invention to make use of the heat dissipated from the warm section of the Stirling refrigerating engine to improve the

functions of the cold stocker, while reducing the power consumption thereof.

To achieve the above described objects, according to one aspect of the present invention, a cold stocker is structured as described below. In a cold stocker that uses a Stirling refrigerating engine to cool a compartment thereof, heat of a warm section of the Stirling refrigerating engine is transferred to a refrigerant in a gas-liquid two-phase condition so as to use for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting of a compartment-cooling heat exchanger.

With this structure, the heat of the warm section of the Stirling refrigerating engine is transferred to the refrigerant in a gas-liquid two-phase condition so as to be used for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on the cold stocker wall, and defrosting of the compartment-cooling heat exchanger. Hence, the heat dissipated from the warm section of the Stirling refrigerating engine can be used effectively for tasks such as promoting evaporation in drainage, preventing dew condensation on the cold stocker wall, and defrosting of the compartment-cooling heat exchanger. This makes it possible to achieve maintenance-free drainage. This also makes it possible to prevent dew condensation on the cold stocker wall and to defrost the compartment-cooling heat exchanger without using an electric heater. This improves the performance and the user-friendliness of the cold stocker, and keeps the power consumption lower than in a case where an electric heater is used for heating.

From drained water, part where there is concern of dew condensation, and the compartment-cooling heat exchanger, cold having a temperature lower than the ambient temperature is collected and used to cool the warm section of the Stirling refrigerating engine, and this helps improve the heat dissipation efficiency of the whole heat dissipation system. The COP of the Stirling refrigerating engine is also improved so as to reduce the power

consumption of the cold stocker.

Furthermore, since the refrigerant is used in a gas-liquid two-phase condition, latent heat can be used, through evaporation and condensation of the refrigerant, to realize heat exchange. This helps keep thermal resistance low, and thereby improves the heat dissipation efficiency. Hence, the heat exchange efficiency is significantly improved, the efficiency of the Stirling refrigerating engine is improved, and the power consumption can be reduced.

According to another aspect of the present invention, a cold stocker is structured as described below. In a cold stocker that uses a Stirling refrigerating engine to cool a compartment thereof, there are formed: a first warm-side refrigerant circulation circuit for dissipating heat of a warm section of the Stirling refrigerating engine to outside the cold stocker; and a second warm-side refrigerant circulation circuit for using the heat of the warm section for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting of a compartment-cooling heat exchanger.

With this structure, by forming the first warm-side refrigerant circulation circuit through which heat of the warm section of the Stirling refrigerating engine is dissipated to outside the cold stocker, heat of the warm section can be dissipated stably. In addition, by forming the second warm-side refrigerant circulation circuit that is used for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on the cold stocker wall, and defrosting of the compartment-cooling heat exchanger, the heat dissipated from the warm section of the Stirling refrigerating engine can be used effectively for tasks such as promoting evaporation in drainage, preventing dew condensation on the cold stocker wall, and defrosting of the compartment-cooling heat exchanger. This makes it possible to achieve maintenance-free drainage. This also makes it possible to prevent dew condensation on the cold stocker wall and to defrost the compartment-cooling heat exchanger without using

an electric heater so as to improve the performance and the user-friendliness of the cold stocker, and thus to keep the power consumption lower than in the case where an electric heater is used for heating.

From drained water, part where there is concern of dew condensation, and the compartment-cooling heat exchanger, cold having a temperature lower than the ambient temperature is collected and used to cool the warm section of the Stirling refrigerating engine, and this helps improve the heat dissipation efficiency of the whole heat dissipation system. The COP of the Stirling refrigerating engine is also improved so as to reduce the power consumption of the cold stocker.

According to the present invention, in the cold stocker structured as just described, the first warm-side refrigerant circulation circuit and the second warm-side refrigerant circulation circuit are designed to be independent of each other.

With this structure, since the first warm-side refrigerant circulation circuit and the second warm-side refrigerant circulation circuit are designed to be independent of each other, heat dissipation can be ensured by using the first warm-side refrigerant circulation circuit while using the second warm-side refrigerant circulation circuit in an agile manner so as to promote evaporation in drainage, to prevent dew condensation on the cold stocker wall, and to defrost the compartment-cooling heat exchanger as necessary. This means that a circulation pump in the second warm-side refrigerant circulation circuit does not need to be constantly operated but needs to be operated only when promoting evaporation in drainage or preventing dew condensation around a door is necessary. This helps reduce the power consumption of the circulation pump and prolong the operational lifetime thereof. Furthermore, the part around the door is not heated for an unnecessarily long time, and thus thermal load of the cold stocker can be reduced so as to reduce the power consumption thereof.

According to the present invention, in the cold stocker structured as just described, in the first warm-side refrigerant circulation circuit, the refrigerant is allowed to circulate naturally, and in the second warm-side refrigerant circulation circuit, the refrigerant is made to circulate by forced circulation.

With this structure, in the first warm-side refrigerant circulation circuit, the refrigerant is allowed to circulate naturally, and in the second warm-side refrigerant circulation circuit, the refrigerant is made to circulate by forced circulation. This makes it possible to achieve constant heat dissipation from the first warm-side refrigerant circulation circuit without using artificial energy. On the other hand, in the second warm-side refrigerant circulation circuit, it is possible to make the refrigerant circulate forcibly in an agile manner as necessary in order to dissipate heat or collect cold. This helps achieve efficient cooling without wasting energy unduly.

According to another aspect of the present invention, a cold stocker is structured as described below. A cold stocker that uses a Stirling refrigerating engine to cool a compartment thereof is provided with: a warm-side heat exchanger arranged in a warm section of the Stirling refrigerating engine; a heat-dissipating heat exchanger for dissipating heat into an environment outside the cold stocker; a first warm-side refrigerant circulation circuit that is built as a loop thermosyphon formed between the warm-side heat exchanger and the heat-dissipating heat exchanger; a second warm-side refrigerant circulation circuit that uses heat of the warm section for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting a compartment-cooling heat exchanger; and a circulation pump for pumping out a refrigerant in the warm-side heat exchanger into the second warm-side refrigerant circulation circuit.

With this structure, since the first warm-side refrigerant circulation circuit is built as a

loop thermosyphon between the warm-side heat exchanger formed in the warm section of the Stirling refrigerating engine and the heat-dissipating heat exchanger for dissipating heat into the environment outside the cold stocker, heat can be obtained from the warm-side heat exchanger through the first warm-side refrigerant circulation circuit without using artificial energy. On the other hand, the circulation pump pumps the refrigerant into the second warm-side refrigerant circulation circuit, and thus heat of the warm section can surely be used for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting the compartment-cooling heat exchanger.

According to another aspect of the present invention, a cold stocker is structured as described below. In a cold stocker that uses a Stirling refrigerating engine to cool a compartment thereof, there are formed: a first warm-side refrigerant circulation circuit through which heat of a warm section of the Stirling refrigerating engine is dissipated to outside the cold stocker; and a second warm-side refrigerant circulation circuit that uses heat of the warm section for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting a compartment-cooling heat exchanger, and the first warm-side refrigerant circulation circuit and the second warm-side refrigerant circulation circuit are both connected, in parallel with each other, to a common warm-side heat exchanger arranged in the warm section.

With this structure, there are formed: a first warm-side refrigerant circulation circuit through which heat of a warm section of a Stirling refrigerating engine is dissipated out of a cold stocker; and a second warm-side refrigerant circulation circuit that uses heat of the warm section for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting the compartment-cooling heat exchanger. Moreover, the first warm-side refrigerant circulation circuit and the second warm-side

refrigerant circulation circuit are connected, in parallel with each other, to the common warm-side heat exchanger arranged in the warm section. Thus, even if one of the first and second warm-side refrigerant circulation circuits becomes unusable for some cause, it is possible to continue dissipating heat of the warm section through the other circuit. This makes it easier to avoid a situation where insufficient dissipation of heat causes damage to the Stirling refrigerating engine.

According to the present invention, in the cold stocker structured as just described, a plurality of the warm-side heat exchangers are arranged, and the first warm-side refrigerant circulation circuit and the second warm-side refrigerant circulation circuit are connected in parallel with each of the plurality of the warm-side heat exchangers.

The refrigerant is supplied from all the plurality of the warm-side heat exchangers to the first and second warm-side refrigerant circulation circuits, from which the refrigerant flows back to all the plurality of the warm-side heat exchangers.

Furthermore, the first warm-side refrigerant circulation circuit is built as a loop thermosyphon, and the second warm-side refrigerant circulation circuit is provided with a circulation pump for pumping refrigerant in the warm-side heat exchangers into the second warm-side refrigerant circulation circuit.

Furthermore, the circulation pump is arranged at the most upstream part of the second warm-side refrigerant circulation circuit.

With this structure, the plurality of warm-side heat exchangers are arranged, and the first warm-side refrigerant circulation circuit and the second warm-side refrigerant circulation circuit are connected in parallel with each of the plurality of warm-side heat exchangers, and thus a plurality of warm-side refrigerant circulation circuits remain usable with respect to any one warm-side heat exchanger, and this makes it easier to avoid a situation where the

circulation of refrigerant is suspended because of a circuit blockage.

Furthermore, since all the plurality of warm-side heat exchangers supply the refrigerant to the first and second warm-side refrigerant circulation circuits, from which the refrigerant flows back to all the plurality of the warm-side heat exchangers, it is possible to make all the plurality of the warm-side heat exchangers involved in supplying heat to outside.

Furthermore, since the first warm-side refrigerant circulation circuit is built as a loop thermosyphon, it is possible to obtain heat from the warm-side heat exchanger through the first warm-side refrigerant circulation circuit without using artificial energy. The circulation pump pumps refrigerant into the second warm-side refrigerant circulation circuit, and thus heat of the warm section can surely be used for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on a cold stocker wall, and defrosting the compartment-cooling heat exchanger.

Furthermore, since the circulation pump is arranged at the most upstream part of the second warm-side refrigerant circulation circuit, the conduit resistance from the warm-side heat exchanger through the circulation pump is so low that the refrigerant smoothly flows into the circulation pump. A large conduit resistance in the pipe for supplying the refrigerant to the circulation pump may cause cavitation on the inlet side of the circulation pump to cause the refrigerant to evaporate unnecessarily, and result in poor circulation efficiency. Arranging the circulation pump at the most upstream part of the second warm-side refrigerant circulation circuit helps avoid such a situation.

According to the present invention, in the cold stocker structured as just described, a refrigerant flow-back pipe of the first warm-side refrigerant circulation circuit is connected to the inlet side of the circulation pump.

With this structure, since the refrigerant flow-back pipe of the first warm-side

refrigerant circulation circuit is connected to the inlet side of the circulation pump, the refrigerant that has flowed through the first warm-side refrigerant circulation circuit and has a saturation temperature is mixed with the refrigerant that flows through the second warm-side refrigerant circulation circuit, and this mixing increases the total amount of heat contained in the refrigerant that flows in the second warm-side refrigerant circulation circuit. This helps improve the utilization efficiency of the heat generated by the Stirling refrigerating engine.

According to the present invention, in the cold stocker structured as just described, in one or both of the first and second warm-side refrigerant circulation circuits, the refrigerant is used in a gas-liquid two-phase condition.

With this structure, since the refrigerant is used in a gas-liquid two-phase condition in one or both of the first and second warm-side refrigerant circulation circuits, latent heat is used for heat exchange through evaporation and condensation of the refrigerant, and this makes it possible to keep thermal resistance low and improve heat dissipation efficiency. Hence, the heat exchange efficiency is spectacularly improved, the efficiency of the Stirling refrigerating engine is improved, and the power consumption is reduced.

According to another aspect of the present invention, a cold stocker is structured as described below. In a cold stocker that uses a Stirling refrigerating engine to cool a compartment thereof, a heat exchange portion provided for promoting evaporation in drainage and a heat exchange portion provided for preventing dew condensation on a cold stocker wall are connected in parallel with each other, and this parallel connection configuration is connected in series with a heat exchanger provided in a warm section of the Stirling refrigerating engine so as to form a warm-side refrigerant circulation circuit.

With this structure, since the heat exchange portion provided for promoting evaporation in drainage and the heat exchange portion provided for preventing dew

condensation on the cold stocker wall are connected in parallel with each other, and this parallel connection configuration is connected in series with the heat exchanger provided in the warm section of the Stirling refrigerating engine so as to form the warm-side refrigerant circulation circuit, heat dissipated from the warm section of the Stirling refrigerating engine can be made effective use of for promoting evaporation in drainage and preventing dew condensation. This makes it possible to achieve maintenance-free drainage. This also makes it possible to prevent dew condensation on the cold stocker wall so as to improve the performance and the user-friendliness of the cold stocker, and to keep the power consumption lower than in a case where an electric heater is used for heating.

Furthermore, latent heat is used for heat exchange through evaporation and condensation of the refrigerant, and this makes it possible to keep thermal resistance low, and thus improves heat dissipation efficiency. Hence, the efficiency of the Stirling refrigerating engine is improved, and the power consumption is reduced.

Furthermore, from drained water, part where there is concern of dew condensation, and the compartment-cooling heat exchanger, cold having a temperature lower than the ambient temperature is collected and used to cool the warm section of the Stirling refrigerating engine, and this helps improve the heat dissipation efficiency of the whole heat dissipation system. The COP of the Stirling refrigerating engine is also improved so as to reduce the power consumption of the cold stocker.

Furthermore, since the heat exchange portion provided for promoting evaporation in drainage and the heat exchange portion provided for preventing dew condensation on the cold stocker wall are connected in parallel with each other, it is possible to reduce the flow resistance of the refrigerant. The reduced flow resistance of the refrigerant, if a circulation pump is used, significantly reduces the power consumption of the circulation pump.

Furthermore, in the parallel connection configuration portion, if a valve is connected in series with each of the heat exchange portion provided for promoting evaporation in drainage and the heat exchange portion provided for preventing dew condensation on the cold stocker wall, it is possible to prevent the refrigerant from flowing in one of the heat exchange portions in which the refrigerant does not need to flow at the moment so as to reduce the load on the circulation pump, and thereby to reduce the power consumption of the circulation pump. In addition, the part around the door is not heated for longer than necessary, and thus thermal load of the cold stocker can be reduced so as to reduce the power consumption thereof.

According to another aspect of the present invention, a cold stocker is structured as described below. In a cold stocker that uses a Stirling refrigerating engine to cool a compartment thereof, a heat exchanger provided in the warm section of the Stirling refrigerating engine, a heat exchange portion provided for promoting evaporation in drainage, and a heat exchange portion provided for preventing dew condensation on a cold stocker wall are connected in series so as to form a warm-side refrigerant circulation circuit.

With this structure, since the heat exchanger provided in the warm section of the Stirling refrigerating engine, the heat exchange portion provided for promoting evaporation in drainage, and the heat exchange portion provided for preventing dew condensation on the cold stocker wall are connected in series so as to form the warm-side refrigerant circulation circuit, heat dissipated from the warm section of the Stirling refrigerating engine can be used effectively for promoting evaporation in drainage and preventing dew condensation. This makes it possible to achieve maintenance-free drainage. This also makes it possible to prevent dew condensation on the cold stocker wall without using an electric heater so as to improve the performance and the user-friendliness thereof, as well as to keep the power

consumption lower than in a case where an electric heater is used for heating.

Furthermore, since the heat exchanger provided in the warm section of the Stirling refrigerating engine, the heat exchange portion provided for promoting evaporation in drainage, and the heat exchange portion provided for preventing dew condensation on the cold stocker wall are connected in series, the piping arrangement is so simple that the number of steps in assembly can be reduced.

According to the present invention, in the cold stocker structured as just described, a cold-side refrigerant circulation circuit is formed including a heat exchanger arranged in the cold section of the Stirling refrigerating engine and a compartment-cooling heat exchanger. Furthermore, a heat exchange portion for defrosting is provided so as to face the compartment-cooling heat exchanger, and a warm-side refrigerant circulation circuit is formed including this heat exchange portion for defrosting and the heat exchanger provided in the warm section of the Stirling refrigerating engine.

With this structure, since the cold-side refrigerant circulation circuit is formed to include the heat exchanger arranged in the cold section of the Stirling refrigerating engine and the compartment-cooling heat exchanger, the heat exchange portion for defrosting is provided so as to face the compartment-cooling heat exchanger, and a warm-side refrigerant circulation circuit is formed including this heat exchange portion for defrosting and the heat exchanger provided in the warm section of the Stirling refrigerant engine, it is possible to carry out defrosting without using an electric heater for defrosting. The cold of frost is collected so as to cool the warm section, and this reduces thermal load on the heat dissipation system, and thus heat dissipation efficiency of the whole heat dissipation system is improved.

According to the present invention, in the cold stocker structured as just described, a heat storage portion is formed in the warm-side refrigerant circulation circuit that includes the

heat exchange portion and the heat exchanger disposed in the warm section of the Stirling refrigerating engine.

With this structure, since the heat storage portion is formed in the warm-side refrigerant circulation circuit that includes the heat exchange portion and the heat exchanger disposed in the warm section of the Stirling refrigerating engine, it is possible, even if the Stirling refrigerating engine is off, to carry out defrosting by making use of heat stored in the heat storage portion. The cold of frost is collected by the heat storage portion, and is used for cooling the warm section during a normal operation. This reduces thermal load on the heat dissipation system, and thus heat dissipation efficiency of the whole heat dissipation system is improved. Hence, the Stirling refrigerating engine 30 operates with an enhanced COP, and thus the power consumption is reduced.

Brief description of drawings

FIG. 1 is a sectional view of a cold stocker.

FIG. 2 is a piping arrangement diagram showing a cold stocker according to a first embodiment of the present invention.

FIG. 3 is a piping arrangement diagram showing a cold stocker according to a second embodiment of the present invention.

FIG. 4 is a piping arrangement diagram showing a cold stocker according to a third embodiment of the present invention.

FIG. 5 is a piping arrangement diagram showing a cold stocker according to a fourth embodiment of the present invention.

FIG. 6 is a piping arrangement diagram showing a cold stocker according to a fifth embodiment of the present invention.

FIG. 7 is a piping arrangement diagram showing a cold stocker according to a sixth

embodiment of the present invention.

FIG. 8 is a piping arrangement diagram showing a cold stocker according to a seventh embodiment of the present invention.

FIG. 9 is a piping arrangement diagram showing a cold stocker according to an eighth embodiment of the present invention.

FIG. 10 is a piping arrangement diagram showing a cold stocker according to a ninth embodiment of the present invention.

FIG. 11 is a piping arrangement diagram showing a cold stocker according to a tenth embodiment of the present invention.

FIG. 12 is a piping arrangement diagram showing a cold stocker according to an eleventh embodiment of the present invention.

FIG. 13 is a piping arrangement diagram showing a cold stocker according to a twelfth embodiment of the present invention.

FIG. 14 is a piping arrangement diagram showing a cold stocker according to a thirteenth embodiment of the present invention.

FIG. 15 is a piping arrangement diagram showing a cold stocker according to a fourteenth embodiment of the present invention.

FIG. 16 is a piping arrangement diagram showing a cold stocker according to a fifteenth embodiment of the present invention.

FIG. 17 is a piping arrangement diagram showing a cold stocker according to a sixteenth embodiment of the present invention.

Best mode for carrying out the invention

Hereinafter, embodiments of the present invention will be explained with reference to the accompanying drawings.

FIG. 1 is a sectional view showing a cold stocker. A cold stocker 1 is for preserving food, and is provided with a housing 10 having a thermal insulation structure. The housing 10 is provided with three cooling compartments 11, 12, and 13 formed one over another. The cooling compartments 11, 12, and 13 have openings, one each, on the front side of the housing 10 (in FIG. 1, on the left side), and these openings are closed with thermal insulation doors 14, 15, and 16, respectively, that are fitted freely openable and closable. On the back face of the thermal insulation doors 14, 15, and 16, gaskets 17 are attached, one each, so as to enclose the openings of the cooling compartments 11, 12, and 13, respectively, when the thermal insulation doors are shut. Inside the cooling compartments 11, 12, and 13, a shelf suitable for the type of food stored therein is arranged as necessary.

From a top, to a rear, and further to a bottom of the housing 10, a cooling system and a heat dissipation system are arranged having a Stirling refrigerating engine as their main component. FIG. 1 (sectional view) and FIG. 2 (piping arrangement diagram) show a first embodiment thereof.

In a corner between the top and the rear of the housing 10, a mounting space 19 is formed, in which a Stirling refrigerating engine 30 is mounted. Part of the Stirling refrigerating engine 30 is a cold section, to which a cold-side heat exchanger 41 is fitted. In the back of the cooling compartment 13, a compartment-cooling heat exchanger 42 is mounted. The cold-side heat exchanger 41 and the compartment-cooling heat exchanger 42 are connected to each other via a refrigerant pipe so as to form a cold-side refrigerant circulation circuit 40 (see FIG: 2). The cold-side refrigerant circulation circuit 40 is charged with a natural refrigerant such as $CO2$. Inside the cold-side heat exchanger 41, a large number of fins are arranged, and this makes it possible to achieve efficient heat exchange between the refrigerant and the cold-side heat exchanger 41.

Inside the housing 10, there is provided a duct 20 for distributing to the cooling compartments 11, 12, and 13 air from which heat has been absorbed by the compartment-cooling heat exchanger 42. In the duct 20, there are properly located cold air outlets that communicate with the cooling compartments 11, 12, and 13. Inside the duct 20, there are properly located blower fans 22 for forcibly sending cold air to the cooling compartments 11, 12, and 13.

The housing 10 is also provided with a duct, which is not illustrated, for collecting air from the cooling compartments 11, 12, and 13. This duct has an air outlet below the compartment-cooling heat exchanger 42, and supplies the compartment-cooling heat exchanger 42 with air to be cooled as indicated by the dotted line arrow in FIG. 1.

Below the compartment-cooling heat exchanger 42, a drain chute 25 is arranged. The drain chute 25 collects drain that drips from the compartment-cooling heat exchanger 42, and permits the collected drain to flow into a drain pan 26.

Another part of the Stirling refrigerating engine 30 is a warm section, to which a warm-side heat exchanger is fitted. In the first embodiment, the warm-side heat exchanger is composed of a first warm-side heat exchanger 51 and a second warm-side heat exchanger 61, both of which are half-ring shaped. Inside both the first warm-side heat exchangers 51 and the second warm-side heat exchanger 61, a large number of fins are arranged, and this makes it possible to achieve efficient heat exchange between the refrigerant and the first and second warm-side heat exchangers 51 and 61.

If the warm-side heat exchanger is whole-ring-shaped, in order to fit it firmly to the warm section of the Stirling refrigerating engine 30, a strict shape control is required so as to obtain sufficient fitting accuracy. In this embodiment, by contrast, since the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61 are half-ring shaped, it is

possible to control the contact pressure between the warm section and them by controlling the fastening pressure when they are fastened with the warm section of the Stirling refrigerating engine in between. This reduces the chance of a situation where an insufficient contact pressure resulting from a dimensional tolerance causes the heat transfer coefficient to decrease. The same is true in a case where the warm-side heat exchanger is divided into more blocks of a ring.

A first warm-side refrigerant circulation circuit 50 is built so as to include the first warm-side heat exchanger 51, and a second warm-side refrigerant circulation circuit 60 is built so as to include the second warm-side heat exchanger 61. The first warm-side refrigerant circulation circuit 50 is composed of the first warm-side heat exchanger 51, a heat-dissipating heat exchanger 52 arranged on the top of the housing 10, and a refrigerant pipe that connects these so as to form a closed loop. The heat-dissipating heat exchanger 52 is for dissipating heat into the environment outside the cold stocker, and is provided with a blower fan 53. The first warm-side refrigerant circulation circuit 50 is charged with water (which may be a water solution) or a hydrocarbon refrigerant. The first warm-side refrigerant circulation circuit 50 functions as a loop thermosyphon, and permits the refrigerant to circulate naturally.

The second warm-side refrigerant circulation circuit 60 is composed of the second warm-side heat exchanger 61, heat exchange portions 62 and 63, a circulation pump 64 for forcibly circulating the refrigerant, and a refrigerant pipe that connects these. The second warm-side refrigerant circulation circuit 60 is charged with a natural refrigerant such as water.

Incidentally, in this specification, of the second warm-side heat exchanger 61, the side from which the refrigerant is discharged is referred to as "the most upstream part" of the second warm-side refrigerant circuit 60. The circulation pump 64 is arranged at this most

upstream part.

Part of the pipe is formed in zigzags so as to serve as the heat exchange portion 62, which is arranged below the drain pan 24 for the purpose of heating the drain collected in the drain pan 24 with the heat of the refrigerant so as to promote evaporation thereof.

Part of the pipe is extended so as to run around the openings of the cooling compartments 11, 12, and 13 so as to serve as the heat exchange portion 63, which heats that part with the heat of the refrigerant in order to prevent dew condensation there.

Next, how a cold stocker 1 operates will be described.

When the Stirling refrigerating engine 30 starts to be driven, the cold section thereof is cooled and the temperature of the warm section thereon rises. Heat is absorbed from the cold-side heat exchanger 41, and the refrigerant in the cold-side heat exchanger 41 is condensed and flows through the cold-side refrigerant circulation circuit 40 into the compartment-cooling heat exchanger 42.

The refrigerant that has flowed into the compartment-cooling heat exchanger 42 evaporates in the compartment-cooling heat exchanger 42, lowering the surface temperature of the compartment-cooling heat exchanger 42. The air that flows through the compartment-cooling heat exchanger 42 is deprived of heat so as to become cold air, blows out from the cold air outlet in the duct 20 into the cooling compartments 11, 12, and 13, and lowers the temperatures in the cooling compartment 11, 12, and 13. Thereafter, the air flows though the unillustrated duct and flows back to the compartment-cooling heat exchanger 42.

The evaporated refrigerant flows through the cold-side refrigerant circulation circuit 40 and flows back to the cold-side heat exchanger 41, and is deprived of heat so as to be condensed. Then, the condensed refrigerant again flows to the compartment-cooling heat exchanger 42.

The heat generated by the Stirling refrigerating engine 30 operating is dissipated from the warm section, and so is the heat that the cold section has collected from the inside of the cooling compartments. This heat heats the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61.

When the first warm-side heat exchanger is heated, the refrigerant inside thereof evaporates, and flows into the heat-dissipating heat exchanger 52. The blower fan 53 blows air to the surface of the heat-dissipating heat exchanger 52, and thus heat is absorbed from the refrigerant inside and the refrigerant becomes condensed. The condensed refrigerant flows back to the first warm-side heat exchanger 51, and evaporates again. In this way, the cycle is repeated in which the refrigerant receives heat from the warm section of the Stirling refrigerating engine 30 so as to evaporate and then gives the heat to cooling air at the heat-dissipating heat exchanger 52 so as to be condensed.

In the first warm-side refrigerant circulation circuit 50, the refrigerant is used in a two-phase condition where the gas phase and the liquid phase coexist. In heat exchange accompanied by phase changes between vapor and liquid, latent heat is exploited through evaporation and condensation of a refrigerant. This makes it possible to significantly improve heat transfer coefficient, compared with in heat exchange which is not accompanied by phase changes.

What is just described will be explained. The value of the amount of heat Q dissipated from the Stirling refrigerating engine 30 is given by the following formula:

$$Q = h A / \Delta Tm$$

where

h is heat transfer coefficient;

A is heat transfer area; and

Δ Tm is temperature difference.

Accordingly, the higher the heat transfer coefficient is, the lower the temperature of the warm section of the Stirling refrigerating engine 30 can be made, resulting in an enhanced COP.

In general, when a refrigerant is used in a brine method which is not accompanied by phase changes, the heat transfer coefficient is in the range of from several hundred to a thousand w/m2k. Furthermore, the heat transfer coefficient is proportional to the power consumption of a pump for circulating brine.

In contrast, in the heat exchange accompanied by phase changes between vapor and liquid, in which latent heat is exploited through evaporation and condensation of a refrigerant, it is possible to obtain a heat transfer coefficient in the range of 3000 to 10000 w/m2k. The value of the heat transfer coefficient is from several times to ten and several times larger than that in a brine method.

In the first warm-side refrigerant circulation circuit 50, the refrigerant is circulated in a gas-liquid two-phase condition as described above, and thus heat exchange can be carried out efficiently. The thermal resistance that arises during heat exchange is extremely low, and thus under similar conditions (similar ambient temperature, similar amount of dissipated heat), the temperature of the warm section of the Stirling refrigerating engine 30 is kept lower. Hence, the Stirling refrigerating engine 30 operates with an enhanced COP, and thus the power consumption is reduced.

When the second warm-side heat exchanger 61 is heated, the refrigerant evaporates. Also here, the refrigerant is used in a gas-liquid two-phase condition. The refrigerant in a gas-liquid two-phase condition is pumped into the heat exchange portions 62 and 63 by the circulation pump 64.

The refrigerant first flows through the heat exchange portion 62, and transfers heat to the drain pan 26 located above it. Hence, the temperature of the drain in the drain pan 26 rises without being heated with an electric heater, and thus evaporation of the drain is promoted. This eliminates the need to empty the drain pan 26 of the drain collected therein, and this makes it possible to achieve maintenance-free drainage.

Subsequently, the refrigerant flows through the heat exchange portion 63 so as to heat the vicinities of the openings of the cooling compartments 11, 12, and 13. Dew is liable to be condensed around where the gaskets 17 come in contact with the housing 10, that is, the boundary area between the inside and the outside of the cooling compartments. By permitting the refrigerant to flow, however, the temperature of the places of the cold stocker wall exposed to the ambient air is kept higher than the dew-point temperature, and thus dew condensation can be prevented without using an electric heater.

The refrigerant collects cold from drain at the heat exchange portion 62, and collects cold from the housing 10 at the heat exchange portion 63. After collecting cold in this way, the refrigerant which has been in the gas phase converts to the liquid phase, and flows into the second warm-side heat exchanger 61 in a single phase, that is, the liquid phase. There, the refrigerant in the liquid phase comes in contact with the refrigerant in the gas phase and converts it into the liquid phase so as to lower the vapor pressure. Thus, evaporation of the refrigerant in the liquid phase is promoted and a gas-liquid two-phase condition of the refrigerant is restored. In this way, a cycle is repeated in which the refrigerant receives heat from the warm section of the Stirling refrigerating engine 30 so as to evaporate and then, at the heat exchange portions 62 and 63, dissipates the heat so as to be condensed so as to collect cold. When the circulation pump 64 stops its operation, this cycle is suspended.

The refrigerant supplies heat to drain and the vicinities of the openings of the cooling

compartments 11, 12, and 13, and in exchange therefor, collects cold having a temperature lower than the ambient temperature so as to cool the warm section of the Stirling refrigerating engine 30 therewith. This reduces the thermal load on the heat dissipation system, and thus improves the heat dissipation efficiency of the whole heat dissipation system. Hence, the Stirling refrigerating engine can be operated with an enhanced COP so as to reduce the power consumption.

The first warm-side refrigerant circulation circuit 50 and the second warm-side refrigerant circulation circuit 60 are designed to be independent of each other, and are arranged in parallel with each other. This makes it possible for the first and second warm-side refrigerant circulation circuits 50 and 60 to carry out heat dissipation without depending on each other. This means that flexible control of operation modes is possible based on the thermal load condition of the cold stocker 1. For example, instead of operating the circulation pump 64 continuously, it is possible to operate it only when promotion of evaporation in drainage or prevention of dew condensation around the door is needed. This makes it possible to reduce the power consumption of the circulation pump 64 and to prolong the operational lifetime thereof.

Furthermore, since the circulation pump 64 is arranged at the most upstream part of the second warm-side circulation circuit 60, the conduit resistance from the second warm-side heat resistance 61 through the circulation pump 64 is low, and this permits the refrigerant to smoothly flow into the circulation pump 64. A large resistance in the pipe through which the refrigerant is supplied to the circulation pump 64 may cause cavitation on the inlet side of the circulation pump 64 to allow the refrigerant to evaporate unnecessarily, and result in poor circulation efficiency. Arranging the circulation pump at the most upstream part of the second warm-side refrigerant circulation circuit 60, however, helps avoid such a situation.

In regard to a gas-liquid two-phase condition of the refrigerant, in the second warm refrigerant circulation circuit 60, at the heat exchange portions 62 and 63, around where drain processing and prevention of dew condensation is performed, the refrigerant may exist solely in the liquid phase. When the refrigerant solely in the liquid phase flows back to the second warm-side heat exchanger 61, latent heat exchange takes place between the returning liquid refrigerant and the refrigerant vapor, and thus highly efficient heat exchange can be achieved here.

Next, a second and further embodiments will be described with reference to FIG. 3 and the following drawings. FIGS. 3 to 17 are piping arrangement diagrams, and the piping arrangements illustrated therein are assumed to be realized in the cold stocker 1 shown in FIG. 1. Such components as find their counterparts in the first embodiment are identified with common reference numerals, and overlapping descriptions will not be repeated.

The second embodiment of the cold stocker of the present invention is illustrated in FIG. 3. Here, the heat exchange portion 62 for promoting evaporation in drainage and the heat exchange portion 63 for preventing dew condensation on the cold stocker wall are connected in parallel with each other, and this parallel connection configuration is connected in series with the second warm-side heat exchanger 61 and the circulation pump 64. In this embodiment, too, the circulation pump 64 is arranged at the most upstream part of the second warm-side refrigerant circulation circuit 60. Inside the parallel connection configuration, a valve 65 is connected to the heat exchange portion 62 at the upstream side thereof, and a valve 66 is connected in series with the heat exchange portion 63 at the upstream side thereof.

With the above structure, the flow resistance of the refrigerant at the heat exchange portions 62 and 63 is approximately half that in the first embodiment, and thus the power consumption of the circulation pump 64 is reduced significantly. Furthermore, since the

valves 65 and 66 are connected with the heat exchange portions 62 and 63, respectively, if whichever of promotion of evaporation in drainage and prevention of dew condensation on the cold stocker wall is not needed, whichever of the valve not needed may be shut so as to stop the refrigerant from flowing therethrough. This reduces the load on the circulation pump, and helps further reduce the power consumption of the circulation pump 64.

The valve 66 may be kept closed unless necessary to prevent condensation. This prevents the part around the doors 14, 15, and 16 from being heated longer than necessary. In this way, it is possible to reduce the thermal load on the cooling compartments 11, 12, and 13, and thereby save power consumption.

Instead of two valves dedicated to the heat exchange portions 62 and 63, respectively, a three-way valve may be shared that is switched to select one of the following three states: the refrigerant flowing through both of the heat exchange portions 62 and 63; the refrigerant flowing through only the heat exchange portion 62; and the refrigerant flowing through only the heat exchange portion 63. In order to achieve easy automatic control, it is preferable that the valve be a solenoid valve.

Incidentally, the refrigerant that flows through the first warm-side refrigerant circulation circuit 50 is in a gas-liquid two-phase condition, and so is the refrigerant that flows through the second warm-side refrigerant circulation circuit 60.

A third embodiment of the cold stocker of the present invention is illustrated in FIG. 4. In a humid environment, promotion of evaporation in drainage and prevention of dew condensation on the cold stocker wall need to be carried out continuously, and the piping arrangement of the third embodiment is suitable for such a case.

In the third embodiment, the warm-side heat exchanger 71 built as one block is fitted to the warm section of the Stirling refrigerant engine 30. As in the first warm-side heat

exchanger 51 and the second warm-side heat exchanger 61, a great number of fins are provided in the warm-side heat exchanger 71 so as to achieve efficient heat exchange with the refrigerant. To the warm-side heat exchanger 71, there are connected the circulation pump 64, the heat exchange portion 62 for promoting evaporation in drainage, the heat exchange portion 63 for preventing dew condensation on the cold stocker wall, and heat exchanger 52 for dissipating heat in this order from the upstream of the flow of the refrigerant to form a serial circuit so as to form a warm-side refrigerant circulation circuit 70.

When the Stirling refrigerating engine 30 is driven, the warm-side heat exchanger 71 is heated. When the warm-side heat exchanger 71 is heated, the refrigerant starts evaporating so as to be in a gas-liquid two-phase condition. The circulation pump 64 that is arranged at the most upstream part of the warm-side refrigerant circulation circuit 70 pumps the refrigerant in the two phases into the heat exchange portion 62.

The refrigerant in a gas-liquid two-phase condition flows through the heat exchanging portion 62, and thus transfers heat to the drain pan 26 so as to promote evaporation of the drained water collected therein. Subsequently, the refrigerant flows through the heat exchange portion 63, and transfers heat to the places of the cold stocker wall in contact with the ambient air so as to keep the temperature of the places higher than the dew-point temperature.

The refrigerant collects cold from drain at the heat exchange portion 62 and from the housing 10 at the heat exchange portion 63. Now, with a large proportion thereof back in the liquid phase, the refrigerant flows into the heat-dissipating heat exchanger 52. Because the blower fan 53 blows air to the surface of the heat-dissipating heat exchanger 52, more heat is absorbed from the refrigerant, and thus more refrigerant is converted into liquid. Now, mostly in a single, liquid phase, the refrigerant flows back to a warm-side heat exchanger 71.

Here, part of the refrigerant evaporates so as to restore a two-phase state of vapor and liquid. In this way, a cycle is repeated in which the refrigerant receives heat from the warm section of the Stirling refrigerating engine 30 so as to evaporate and then, at the heat exchange portions 62 and 63, is condensed by dissipating the heat so as to collect cold. When the circulation pump 64 stops its operation, this cycle is suspended.

With the above structure, the piping arrangement in the warm-side refrigerant circulation circuit 60 can be advantageously simple and the number of steps in the assembly process can be advantageously reduced.

The arrangement of the heat exchange portions 62 and 63 may be reversed, that is, they may be so located that the cold stocker wall is first heated and then the drain pan 26 is heated. It is preferable that heat be delivered by a refrigerant in the phases of vapor and liquid. However, a brine method may instead be adopted in which heat is delivered in the liquid phase only.

A fourth embodiment of the cold stocker of the present invention is illustrated in FIG. 5. In the fourth embodiment, too, the warm-side heat exchanger 71 built as one block is fitted to the warm section of the Stirling refrigerating engine 30. Inside the warm-side heat exchanger 71, a large number of fins are provided so as to achieve efficient heat exchange with the refrigerant. The circulation pump 64 is connected to the downstream side of the warm-side heat exchanger 71, and the heat-dissipating heat exchanger 52 is connected to the upstream side thereof.

Between the circulation pump 64 and the heat-dissipating heat exchanger 52 are arranged heat exchange portion 62 for promoting evaporation in drainage and heat exchange portion 63 for preventing dew condensation on the cold stocker wall. The heat exchange portions 62 and 63 are not connected in series as in the third embodiment but in parallel with

each other as in the second embodiment. This parallel connection configuration is connected in series with the warm-side heat exchanger 71 and the circulation pump 64. Inside the parallel connection configuration, the valve 65 is connected in series with the heat exchange portion 62 on the upstream side thereof and the valve 66 is connected in series with the heat exchange portion 63 on the upstream side thereof. Thus, the warm-side refrigerant circulation circuit 70 is formed.

When the Stirling engine 30 is driven, the warm-side heat exchanger 71 is heated. When the warm-side heat exchanger 71 is heated, part of the refrigerant therein evaporates, and thus the refrigerant comes to exist in a gas-liquid two-phase condition. The circulation pump 64 that is arranged at the most upstream part of the warm-side refrigerant circulation circuit 70 pumps the refrigerant in the two phases into the heat exchange portions 62 and 63.

The refrigerant is split into two streams to flow through the heat exchange portions 62 and 63, and transfers heat to the drain pan 26 to promote evaporation in drainage and transfers heat to part of the cold stocker wall exposed to the ambient air to keep the temperature thereof higher than the dew-point temperature.

The refrigerant collects cold from drain at the heat exchange portion 62 and from the housing 10 at the heat exchange portion 63. Now, with a large proportion thereof back in the liquid phase, the refrigerant flows into the heat-dissipating heat exchanger 52. Because the blower fan 53 blows air to the surface of the heat-dissipating heat exchanger 52, more heat is absorbed from the refrigerant, and thus more refrigerant is converted into liquid. Now, mostly in a single, liquid phase, the refrigerant flows back to a warm-side heat exchanger 71. Here, part of the refrigerant evaporates so as to restore a gas-liquid two-phase condition. In this way, a cycle is repeated in which the refrigerant receives heat from the warm section of the Stirling refrigerating engine 30 so as to evaporate and then, at the heat exchange portions

62 and 63, is condensed by dissipating the heat so as to collect cold. When the circulation pump 64 stops its operation, this cycle is suspended.

A fifth embodiment of the cold stocker of the present invention is illustrated in FIG. 6. As in the second embodiment, the heat exchange portion 62 for promoting evaporation of drainage and the heat exchange portion 63 for preventing dew condensation on the cold stocker wall are connected in parallel with each other, and this parallel connection configuration is connected in series with the second warm-side heat exchanger 61 and the circulation pump 64. Inside the parallel connection configuration, the valve 65 is connected in series with the heat exchange portion 62 on the upstream side thereof and the valve 66 is connected in series with the heat exchange portion 63 on the upstream side thereof.

In the fifth embodiment, to the parallel connection configuration of the heat exchange portions 62 and 63 is connected, in parallel therewith a defrosting refrigerant circulation circuit 80. The defrosting refrigerant circulation circuit 80 includes a defrosting heat exchanger 81 and valves 82 and 83 connected to the upstream and downstream sides thereof. The defrosting heat exchanger 81 transfers heat to the compartment-cooling heat exchanger 42 by heat conduction or by convection. A blower fan may be arranged in such a way that it forcibly causes convection between the defrosting heat exchanger 81 and the compartment-cooling heat exchanger 42. Part of the compartment-cooling heat exchanger 42 may be sectioned to be formed into the defrosting heat exchanger 81.

The cooling compartment 11, 12, and 13 are cooled with the valves 65 and 66 opened and the valves 82 and 83 closed. When the Stirling refrigerating engine 30 is driven, heat is absorbed from the cold-side heat exchanger 41, and the refrigerant therein becomes condensed and flows into the compartment-cooling heat exchanger 42 through the cold-side refrigerant circulation circuit 40.

The refrigerant that has flowed into the compartment-cooling heat exchanger 42 is heated to evaporate by the heat of the air that flows therethrough so as to lower the surface temperature thereof. The air that flows through the compartment-cooling heat exchanger 42, from which heat is absorbed, becomes cold air and blown through the cold air outlets 21 of the duct 20 into the cooling compartments 11, 12, and 13 so as to lower the temperatures thereof. Thereafter, the air flows through the unillustrated duct to the compartment-cooling heat exchanger 42.

Heat generated by the operation of the Stirling refrigerating engine and heat collected from the inside of the cold stocker by the cold section is to be dissipated from the warm section. With this heat, the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61 are heated.

When the first warm-side heat exchanger 51 is heated, part of the refrigerant therein evaporates, and thus the refrigerant in the gas phase flows into the heat-dissipating heat exchanger 52. The blower fan 53 blows air to the surface of the heat-dissipating heat exchanger 52 so as to absorb heat of the refrigerant in the gas phase, and thus the refrigerant in the gas phase becomes condensed. The refrigerant that has been condensed into the liquid phase flows back to the first warm-side heat exchanger 51 to evaporate again. In this way, a cycle is repeated in which the refrigerant receives heat from the warm section of the Stirling refrigerating engine 30 so as to evaporate and then, at the heat-dissipating heat exchanger 52, transfers the heat to air for cooling so as to be condensed.

When the second warm-side heat exchanger 61 is heated, part of the refrigerant therein evaporates, and thus the refrigerant comes to exist in a gas-liquid two-phase condition. The circulation pump 64 that is arranged at the most upstream part of the second warm-side refrigerant circulation circuit 60 pumps the refrigerant in the two phases into the heat

exchange portions 62 and 63. The refrigerant is split into two streams to flow through the heat exchange portions 62 and 63, and transfers heat to the drain pan 26 to promote evaporation in drainage and transfers heat to part of the cold stocker wall exposed to the ambient air to keep the temperature thereof higher than the dew-point temperature.

The refrigerant collects cold from drain at the heat exchange portion 62 and from the housing 10 at the heat exchange portion 63, so that the condensation of the vapor part of the refrigerant proceeds. Thus, the refrigerant flows back to the second warm-side heat exchanger 61 nearly completely in the liquid phase. Part of the refrigerant evaporates so as to restore a two-phase state of vapor and liquid. In this way, a cycle is repeated in which the refrigerant receives heat of the warm section of the Stirling refrigerating engine 30 so as to evaporate and then, at the heat exchange portions 62 and 63, is condensed by dissipating the heat so as to collect cold. The valves 82 and 83 are closed, so that the heat of the refrigerant is not transferred to the compartment-cooling heat exchanger 42. When the circulation pump 64 stops its operation, this cycle is suspended.

When the surface temperature of the compartment-cooling heat exchanger 42 lowers, heat is absorbed from air that flows through the compartment-cooling heat exchanger 42, and thus the air becomes cold air. Simultaneously, moisture contained in the air, that is, moisture that has flowed into the cooling compartments 11, 12, and 13 and moisture that has evaporated from food stored in the cooling compartments sticks to the compartment-cooling heat exchanger 42 as frost. Frost, for its thermal insulation property, reduces the heat exchange efficiency between the compartment-cooling heat exchanger 42 and the air. Furthermore, frost narrows the gaps between the fins of the compartment-cooling heat exchanger 42. This further reduces the cooling capacity.

To prevent this, the valves 82 and 83 are opened with proper timing so as to permit the

refrigerant from the second warm-side heat exchanger 61 to flow into the defrosting heat exchanger 81. Thus, heat of the refrigerant is transferred to the compartment-cooling heat exchanger 42 so as to melt the frost stuck thereto. The melted frost flows into the drain pan 26 as drain.

The cold of the compartment-cooling heat exchanger 42, and mainly, the cold of frost is collected by the refrigerant. The refrigerant that has collected cold to be colder and become further condensed into liquid flows back to the second warm-side heat exchanger 61, and again turns back into a gas-liquid two-phase condition. For higher defrosting efficiency and shorter defrosting time, the valves 65 and 66 are advisably closed during defrosting so that the refrigerant flows exclusively through the defrosting heat exchanger 81.

With this structure, without providing an electric heater for defrosting, it is possible to carry out defrosting of the compartment-cooling heat exchanger 42. Furthermore, cold collected from frost is used to cool the warm section of the Stirling refrigerating engine 30; thus the thermal load on the heat dissipation system is reduced and the heat dissipation efficiency of the whole heat dissipation system is improved.

Since the first warm-side refrigerant circulation circuit 50 is built as a loop thermosyphon, heat can be absorbed from the first warm-side heat exchanger 51 without using an artificial energy. In the second warm-side refrigerant circulation circuit 60, with the refrigerant pumped thereinto by the circulation pump 64, heat of the warm section can surely be used for at least one of tasks of promoting evaporation in drainage, preventing dew condensation on the cold stocker wall, and defrosting of the compartment-cooling heat exchanger.

The defrosting heat exchanger 81 may be connected in series with the parallel connection configuration of the heat exchange portions 62 and 63. In this case the valves 82

and 83 are not required. When the circulation pump 64 is driven with the valves 65 and 66 open, promotion of evaporation in drainage, heating of the cooling compartment wall, and defrosting can be carried out simultaneously. When the valve 65 is closed, promotion of evaporation in drainage becomes suspended, and when the valve 66 is closed, heating of the cooling compartment wall becomes suspended. When the operation of the circulation pump 64 is stopped, the heat exchange portions 62 and 63 and defrosting heat exchanger 81 all stop operating.

A sixth embodiment of the cold stocker of the present invention is illustrated in FIG. 7. The sixth embodiment is structured by adding the following component to the fifth embodiment. That is, a heat storage portion 90 that is of a heat exchanger type is provided between the parallel connection configuration among the heat exchange portions 62 and 63 and the defrosting heat exchanger 81 and the second warm-side heat exchanger 61.

When the Stirling engine is driven with the valves 65 and 66 open and the valves 82 and 83 closed, heat is absorbed from the cold-side heat exchanger 41, and the refrigerant inside it becomes condensed and flows into the compartment-cooling heat exchanger 42. The refrigerant that has flowed into the compartment-cooling heat exchanger 42 evaporates and lowers the surface temperature of the compartment-cooling heat exchanger 42. Thus, the cooling compartment 11, 12, and 13 are cooled.

On the other hand, the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61 are heated. When the first warm-side heat exchanger 51 is heated, part of the refrigerant inside it evaporates and flows into the heat-dissipating heat exchanger 52 in the gas phase. The blower fan 53 blows air to the surface of the heat-dissipating heat exchanger 52 so as to absorb heat of the refrigerant in the gas phase, and thus the refrigerant in the gas phase is condensed. The refrigerant that has been condensed into the liquid phase flows

back to the first warm-side heat exchanger 51 and evaporates again. In this way, a cycle is repeated in which the refrigerant receives heat from the warm section of the Stirling refrigerating engine 30 so as to evaporate and then, at the heat-dissipating heat exchanger 52, transfers the heat to air for cooling so as to be condensed.

When the second warm-side heat exchanger 61 is heated, part of the refrigerant therein evaporates, and thus the refrigerant comes to be in a gas-liquid two-phase condition. The circulation pump 64 that is arranged at the most upstream part of the second warm-side refrigerant circulation circuit 60 pumps the refrigerant in the two phases into the heat exchange portions 62 and 63. The refrigerant is split into two streams to flow through the heat exchange portions 62 and 63, and transfers heat to the drain pan 26 to promote evaporation in drainage and transfers heat to part of the cold stocker wall exposed to the ambient air to keep the temperature thereof higher than the dew-point temperature.

The refrigerant that has flowed out of the heat exchange portions 62 and 63 flows through the heat storage portion 90. The heat remaining in the refrigerant after it dissipated heat at the heat exchange portions 62 and 63 is stored in the heat storage portion 90. By transferring the remaining heat to the heat storage portion 90, part of the refrigerant that is in the gas phase is promoted to condense to liquid, and thus the refrigerant flows back to the second warm-side heat exchanger 61 mostly in a single, liquid phase. Part of the refrigerant evaporates so as to restore a gas-liquid two-phase condition. In this way, a cycle is repeated in which the refrigerant receives heat from the warm section so as to evaporate and then, at the heat exchange portions 62 and 63 and the heat storage portion 90, condenses to dissipate heat so as to collect cold. The valves 82 and 83 are closed, so that the heat of the refrigerant is not transferred to the compartment-cooling heat exchanger 42. When the circulation pump 64 stops its operation, this cycle is suspended.

To carry out defrosting of the compartment-cooling heat exchanger 42, the valves 82 and 83 are opened, and the refrigerant that has flowed out of the second warm-side heat exchanger 61 is made to flow into the defrosting heat exchanger 81. Then heat of the refrigerant is transferred to the compartment-cooling heat exchanger 42 so as to melt the frost deposited thereon. The melted frost flows into the drain pan 26 as drain.

The cold of the compartment-cooling heat exchanger 42, and mainly, the cold of frost is collected by the refrigerant. The refrigerant that has collected cold so as to be cooled down exchanges heat with the heat storage portion 90 when it flows therethrough. After transferring cold to and receiving heat from the heat storage portion 90 so as to be heated up, the refrigerant flows back to the second warm-side heat exchanger 61 and restores a gas-liquid two-phase condition. For higher defrosting efficiency and shorter defrosting time, the valves 65 and 66 are advisably closed during defrosting so that the refrigerant flows exclusively through the defrosting heat exchanger 81.

Thus, during a defrosting operation, the cold of frost is stored in the heat storage portion 90. When a defrosting operation is finished and a normal operation starts again, the heat storage portion 90 transfers cold to the refrigerant that flows therethrough, and the refrigerant cools the warm section of the Stirling refrigerant engine 30. The heat storage portion 90, on the other hand, stores heat of the warm section and prepares for the next defrosting operation.

With this structure, without providing an electric heater for defrosting, it is possible to carry out defrosting of the compartment-cooling heat exchanger 42. Even if the Stirling refrigerating engine stops its operation, as long as the circulation pump 64 operates, it is possible to carry out defrosting by heating the refrigerant with heat stored in the heat storage portion 90.

Furthermore, as in the fifth embodiment, the cold collected from frost is used to cool the warm section of the Stirling refrigerating engine 30, the thermal load on the heat dissipation system is reduced and the heat dissipation efficiency of the whole heat dissipation system is improved. Hence, the Stirling refrigerating engine can be operated with an enhanced COP so as to reduce the power consumption.

The defrosting heat exchanger 81 may be connected in series with the parallel connection configuration of the heat exchange portions 62 and 63. In this case, the valves 82 and 83 are not necessary. When the circulation pump 64 is driven with the valves 65 and 66 open, promotion of evaporation in drainage, heating of the cold stocker wall, and defrosting are carried out simultaneously. When the valve 65 is closed, promotion of evaporation in drainage becomes suspended, and when the valve 66 is closed, heating of the cold stocker wall becomes suspended. When the operation of the circulation pump 64 is stopped, the heat exchange portions 62 and 63 and defrosting heat exchanger 81 all stop operating.

A seventh embodiment of the cold stocker of the present invention is illustrated in FIG. 8. The seventh embodiment is identical to the second embodiment except for that the warm-side heat exchanger thereof is built as one block. That is, in this embodiment, the warm-side heat exchanger 71 made of one block is mounted to the warm part of the Stirling engine 30. Inside the warm-side heat exchanger 71, a large number of fins are provided so as to achieve efficient heat exchange with the refrigerant.

The first warm-side refrigerant circulation circuit 50 and the second warm-side refrigerant circulation circuit 60 are formed to include the warm-side heat exchanger 71. That is, the warm-side heat exchanger 71 is a warm-side heat exchanger shared by the first warm-side refrigerant circulation circuit 50 and the second warm-side refrigerant circulation circuit 60, and both of the first warm-side refrigerant circulation circuit 50 and the second warm-side

circulation circuit 60 are connected in parallel with this shared warm-side heat exchanger 71.

An eighth embodiment of the cold stocker of the present invention is illustrated in FIG. 9. In a humid environment, promotion of evaporation in drainage and prevention of dew condensation on the cold stocker wall need to be carried out continuously, and the piping arrangement of the eighth embodiment is suitable for such a case.

The eighth embodiment is identical to the first embodiment except for that the warm-side heat exchanger thereof is built as one block. That is, in this embodiment, the warm-side heat exchanger 71 made of one block is mounted to the warm section of the Stirling engine 30. Inside the warm-side heat exchanger 71, a large number of fins are arranged so as to achieve efficient heat exchange with the refrigerant.

The first warm-side refrigerant circulation circuit 50 and the second warm-side refrigerant circulation circuit 60 are formed to include the warm-side heat exchanger 71. That is, the warm-side heat exchanger 71 is a warm-side heat exchanger shared by the first warm-side refrigerant circulation circuit 50 and the second warm-side refrigerant circulation circuit 60, and both of the first warm-side refrigerant circulation circuit 50 and the second warm-side circulation circuit 60 are connected in parallel with this shared warm-side heat exchanger 71.

With the above structure, the piping arrangement in the warm-side refrigerant circulation circuit 60 can be advantageously simple and the number of steps in the assembly process can be advantageously reduced.

The arrangement of the heat exchange portions 62 and 63 may be reversed, that is, they may be so located that the cold stocker wall is first heated and then the drain pan 26 is heated.

A ninth embodiment of the cold stocker of the present invention is illustrated in FIG. 10. The structure of the ninth embodiment is identical to that of the eighth embodiment

except for the following point. That is, in the eight embodiment, in the first warm-side refrigerant circulation circuit 50, the refrigerant pipe that permits the refrigerant to flow back to the warm-side heat exchanger 71 is connected to the warm-side heat exchanger 71, but in the ninth embodiment, the refrigerant pipe that permits the refrigerant to flow back to the warm-side heat exchanger 71 is connected to the inlet side of the circulation pump 64.

With this structure, the refrigerant that has flowed from the warm-side heat exchanger 71 into the heat-dissipating heat exchanger 52 by natural circulation, when it flows back from the heat-dissipating heat exchanger 52, does not flows directly into the warm-side heat exchanger 71, but joins together with the refrigerant that flows through the second warm-side refrigerant circulation circuit 60. Hence, to the amount of heat of the refrigerant that has flowed from the warm-side heat exchanger 71 into the second warm-side refrigerant circulation circuit 60 is added to the amount of heat of the refrigerant that has flowed back from the heat-dissipating heat exchanger 52 and has a saturation temperature, and this greatly increases the total amount of heat of the refrigerant that flows through the second warm-side refrigerant circulation circuit 60. This increases the amount of heat that is given to the heat exchange portion 62 for promoting evaporation in drainage and the heat exchange portion 63 for preventing dew condensation on the cold stocker wall, leading to an enhanced usage efficiency of heat generated by the Stirling refrigerating engine 30.

A tenth embodiment of the cold stocker of the present invention is illustrated in FIG. 11. The tenth embodiment is structured identically to the fifth embodiment except for that the warm-side heat exchanger thereof is built as one block. With this structure, without providing an electric heater for defrosting, it is possible to carry out defrosting of the compartment-cooling heat exchanger 42. Furthermore, since the cold collected from frost is used to cool the warm section of the Stirling refrigerating engine 30, the thermal load on the

heat dissipation system is reduced and the heat dissipation efficiency of the whole heat dissipation system is improved.

An eleventh embodiment of the cold stocker of the present invention is illustrated in FIG. 12. The eleventh embodiment is structured identically to the sixth embodiment except for that the warm-side heat exchanger thereof is built as one block. With this structure, as in the sixth embodiment, without providing an electric heater for defrosting, it is possible to carry out defrosting of the compartment-cooling heat exchanger 42, and furthermore, even if the Stirling refrigerating engine stops its operation, as long as the circulation pump 64 operates, it is possible to carry out defrosting by heating the refrigerant with the heat stored in the heat storage portion 90.

A twelfth embodiment of the cold stocker of the present invention is illustrated in FIG. 13. The twelfth embodiment is structured by modifying the second embodiment as below. In the second embodiment, the first warm-side heat exchanger 51 is dedicated to the first warm-side refrigerant circulation circuit 50, and the second warm-side heat exchanger 61 is dedicated to the second warm-side refrigerant circulation circuit 60. In the twelfth embodiment, the first warm-side refrigerant circulation circuit and the second warm-side refrigerant circulation circuit share both of the first and second warm-side heat exchangers 51 and 61.

As shown in FIG. 13, in the first warm-side refrigerant circulation circuit 50, two refrigerant pipes come out in parallel with each other, one from each of the first and second warm-side heat exchangers 51 and 61, are joined together so as to be a single pipe along the way, and then enters the heat-dissipating heat exchanger 52. The refrigerant pipe coming out of the heat-dissipating heat exchanger 52 is split into two parallel pipes along the way, so that each, in parallel with each other, enters back the first warm-side heat exchanger 51 and

the second warm-side heat exchanger 61.

In the second warm-side refrigerant circulation circuit 60, a refrigerant pipe comes out, from each of the first and second warm-side heat exchangers 51 and 61, in parallel with each other, are joined together so as to be a single pipe along the way, and enters the circulation pipe 64. The refrigerant pipe coming out from the parallel connection structure of the heat exchange portion 62 for promoting evaporation in drainage and from the heat exchange portion 63 for preventing dew condensation on the cold stocker wall is split along the way so as to enter back, in parallel with each other, the first and second warm-side heat exchangers 51 and 61.

In other words, the first warm-side refrigerant circulation circuit 50 is connected in parallel with the first warm-side heat exchanger 51 and in parallel with the second warm-side heat exchanger 61; and the second warm-side refrigerant circulation circuit 60 is connected in parallel with the first warm-side heat exchanger 51 and in parallel with the second warm-side heat exchanger 61.

With the above structure, from both the first and second warm-side heat exchangers 51 and 61, the refrigerant is supplied to the first and second warm-side refrigerant circulation circuits 50 and 60. Furthermore, into both the first and second warm-side heat exchangers 51 and 61, the refrigerant flows back from the first and second warm-side refrigerant circulation circuits 50 and 60.

With this structure, the first warm-side refrigerant circulation circuit 50 is connected in parallel with the first warm-side heat exchanger 51 and in parallel with the second warm-side heat exchanger 61, and the second warm-side refrigerant circulation circuit 60 is connected in parallel with the first warm-side heat exchanger 51 and in parallel with the second warm-side heat exchanger 61. Thus, with respect to each of the first and second warm-

side heat exchangers, a plurality of warm-side refrigerant circulation circuits can be ensured. Hence, a situation can be easily avoided where a circuit becomes unusable preventing the refrigerant from circulating, resulting in the Stirling refrigerating engine 30 being damaged by insufficient heat dissipation.

In addition, since both in the first and second warm-side heat exchangers 51 and 61, the refrigerant is supplied to and flows back from the first and second warm-side refrigerant circulation circuits 50 and 60, both the first and second warm-side heat exchangers 51 and 61 can be included in dissipating heat to outside and collecting cold from outside.

A thirteenth embodiment of the cold stocker of the present invention is illustrated in FIG. 14. The thirteenth embodiment is structured by modifying the eighth embodiment as below. That is, in the eighth embodiment, the warm-side heat exchanger 71 is built as one block, but in the thirteenth embodiment, a warm-side heat exchanger is separated into two, that is, the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61 are used.

As shown in FIG. 14, in the first warm-side refrigerant circulation circuit 50, from each of the first and second warm-side heat exchangers 51 and 61, a refrigerant pipe comes out in parallel with each other, and are joined together into one refrigerant pipe so as to enter the heat-dissipating heat exchanger 52. The refrigerant pipe coming out of the heat-dissipating heat exchanger 52 is separated into two parallel pipes along the way so that each, in parallel with each other, enters back the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61.

In the second warm-side refrigerant circulation circuit 60, a refrigerant pipe comes out, from each of the first and second warm-side heat exchangers 51 and 61, in parallel with each other, are joined together so as to be a single pipe along the way, and enters the circulation

pump 64. The refrigerant pipe coming out from the heat exchange portion 62 for promoting evaporation in drainage and then from the heat exchange portion 63 for preventing dew condensation on the cold stocker wall is split along the way so as to enter back, in parallel with each other, the first and second warm-side heat exchangers 51 and 61.

In other words, the first warm-side refrigerant circulation circuit 50 is connected in parallel with the first warm-side heat exchanger 51 and in parallel with the second warm-side heat exchanger 61, and the second warm-side refrigerant circulation circuit 60 is connected in parallel with the first warm-side heat exchanger 51 and in parallel with the second warm-side heat exchanger 61.

With the above structure, from both the first and second warm-side heat exchangers 51 and 61, the refrigerant is supplied to the first and second warm-side refrigerant circulation circuits 50 and 60. Furthermore, into both the first and second warm-side heat exchangers 51 and 61, the refrigerant flows back from the first and second warm-side refrigerant circulation circuits 50 and 60.

A fourteenth embodiment of the cold stocker of the present invention is illustrated in FIG. 15. The fourteenth embodiment is structured by modifying the ninth embodiment as below. That is, in the ninth embodiment, the warm-side heat exchanger 71 is built as one block, but in the fourteenth embodiment, a warm-side heat exchanger is separated into two blocks, that is, the first warm-side heat exchanger 51 and the second warm-side heat exchanger 61 are used.

As shown in FIG. 15, in the first warm-side refrigerant circulation circuit 50, from each of the first and second warm-side heat exchangers 51 and 61, a refrigerant pipe comes out in parallel with each other, and are joined together into one refrigerant pipe so as to enter the heat-dissipating heat exchanger 52. A flow-back refrigerant pipe coming out from the

heat-dissipating heat exchanger 52 is connected to the inlet side of the circulation pipe 64.

In the second warm-side refrigerant circulation circuit 60, a refrigerant pipe comes out, from each of the first and second warm-side heat exchangers 51 and 61, in parallel with each other, are joined together so as to be a single pipe along the way, and enters the circulation pipe 64. The refrigerant pipe coming out from the heat exchange portion 62 for promoting evaporation in drainage and then from the heat exchange portion 63 for preventing dew condensation on the cold stocker wall is split along the way so as to enter back, in parallel with each other, the first and second warm-side heat exchangers 51 and 61.

When the first warm-side refrigerant circulation circuit 50 is blocked up, the second warm-side refrigerant circulation circuit 60 can be used to permit the circulation of the refrigerant through the first and second warm-side heat exchangers 51 and 61 to continue, and furthermore, when the circulation pump 64 is out of order so that it cannot send the refrigerant farther therefrom, the circulation of the refrigerant through the first warm-side refrigerant pipe 50 can be continued by making the refrigerant flow backward in the refrigerant pipes that run from the first and second warm-side heat exchangers 51 and 61 through the circulation pump 64. Hence, a situation can be easily avoided where the circuit becomes unusable causing the refrigerant to stop circulating, resulting in the Stirling refrigerating engine 30 being damaged by insufficient heat dissipation.

A fifteenth embodiment of the cold stocker of the present invention is illustrated in FIG. 16. The fifteenth embodiment, as in the fifth and the tenth embodiments, the defrosting refrigerant circulation circuit 80 is connected in parallel with the parallel connection configuration of the heat exchange portions 62 and 63. The defrosting refrigerant circulation circuit 80 includes a defrosting heat exchanger 81 and valves 82 and 83 connected therewith on the upstream side and the downstream side thereof, respectively. The defrosting heat

exchanger 81 transfers heat to the compartment-cooling heat exchanger 42 by heat conduction, convection, or forcible convection by a blower fan.

With this structure, without providing an electric heater for defrosting, it is possible to carry out defrosting of the compartment-cooling heat exchanger 42. Furthermore, the cold collected from frost is used to cool the warm section of the Stirling refrigerating engine 30, the thermal load on the heat dissipation system is reduced, and the heat dissipation efficiency of the whole heat dissipation system is improved. Hence, the Stirling refrigerating engine can be operated with an enhanced COP so as to reduce the power consumption.

A sixteenth embodiment of the cold stocker of the present invention is illustrated in FIG. 17. The sixteenth embodiment is structured by adding the following component to the fifteenth embodiment. That is, as in the sixth and the eleventh embodiments, the heat storage portion 90 that is of a heat exchanger type is provided among: the parallel connection configuration among the heat exchange portions 62 and 63 and the defrosting heat exchanger 81; the first warm-side heat exchanger 51; and the second warm-side heat exchanger 61.

With this structure, without providing an electric heater for defrosting, it is possible to carry out defrosting of the compartment-cooling heat exchanger 42, and furthermore, even if the Stirling refrigerating engine stops its operation, it is possible, solely by operating the circulation pump 64, to carry out defrosting by heating the refrigerant with heat stored in the heat storage portion 90.

Embodiments of the present invention have been explained above, but it should be understood that they are not meant to limit the application of the present invention in any manner, and that various modifications are permissible within the spirit of the present invention.

Industrial applicability

The present invention is a cold stocker for household use or for business use, and is applicable to appliances in general that use a Stirling refrigerating engine as their cold source.